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Electricity demand supply analysis: Current status and future prospects for Maharashtra, India

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ABSTRACT

The growth potential of any state is linked with infrastructure and electricity infrastructure is the most important parameter for economic growth. Maharashtra, a prominent state in India consumes 12 per cent of India's electricity. Maharashtra's power sector is facing the electricity deficit and shortage since early 2005. On the other hand, industrial and service sectors are rising in the state. The present paper discusses electricity situational analysis of the state. Electricity demand analysis has been presented and comparison of state electricity demand vis-à-vis Mumbai's demand (state capital) has been carried out for two years. Variation for monthly average demand for two years and load shedding have also been analyzed. Power supply situation analysis and analysis of major power suppliers have been carried out. The State Load Distribution Center data is used to depict the load variation for a typical day. Interventions needed to sustainably meet the growing demands are also discussed.

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1. Introduction

Energy is at the heart of contemporary living and is a critical input for economic development of the country. Developing countries such as India are facing severe power crisis. The widespread shortage of electricity supply is a basic obstacle to economic growth. The gap between demand and supply is expected to increase in future.

Maharashtra is the second largest state in India in terms of population and area and consumes 12 per cent of India's electricity. The state occupies the western and central part of the country and has a long coastline of nearly 720 km along the Arabian Sea with an area of over 3.08 lac km^2 [1]. The state has a population of around 11.52 Crores [2]. It is a prominent state in India having a vibrant industrial and service sector economy. Both the sectors together contribute about 89 per cent of the state's gross domestic product. Though 55 per cent of the population is dependent on agriculture and allied sectors, they contribute just 11 per cent to the state's income [3]. The state has shown economic growth of 8.4 per cent from 2002 onwards which spurred in demand for electricity. As a result, the state was pushed into an acute shortage of power since 2005 with

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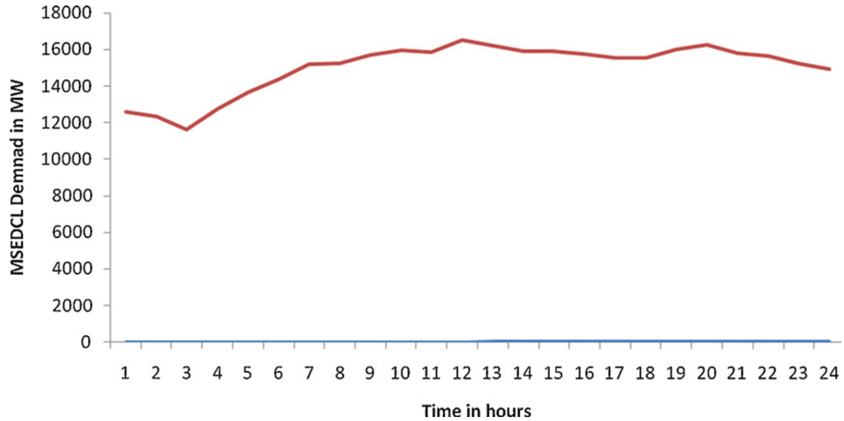

Fig. 1. Typical load curve for 31st March 2011 [11].

peak power shortage of 5000 MW. Large power cuts of 6–14 h have become common. The burden of electricity bills is also increasing because of poor distribution network and higher commercial losses of the order of 35 per cent [4].

Regulatory structure of state electricity sector has undergone a major policy change after 1990. This has enabled the state to adopt strategies such as unbundling of generation, transmission and distribution operations, private sector participation in generation and distribution, rationalized tariffs and reduced political influence. This could enable the state to attract financial support from World Bank, Asian Development Bank, etc. This led to beginning of new era for the state electricity sector [5,6].

Various authors have addressed the issue of analyzing electricity sector with special reference to developing economies. The state electricity sector problems have been analysed by Sant and Dixit a decade back [7,8]. Analysis of Maharashtra's power situation was carried out earlier by More et al. [9]. They have discussed economic constraints prevailing at that time. Totare and Pandit [10] have discussed power sector reforms in Maharashtra.

The present paper discusses electricity situational analysis of the state for various sectors of economy. Electricity demand analysis has been presented and comparison of state electricity demand and Mumbai's demand (state capital) have been carried out for two years. Variations for monthly average demand for two years and load shedding have also been presented. Power supply situation analysis and major power supplier analysis has been carried out. The State Load Distribution (SLDC) data is used to depict the load variation for a typical day. Interventions needed to sustainably meet the growing electricity demands are also discussed.

2. Electricity demand analysis

By analyzing the pattern of required energy and the energy demand met, we can quantify the shortage. The demand for electricity varies during the day with peak demand occurring at morning and evening time of the day. The typical load curve based on hourly pattern from SLDC for 31st March 2011 has been shown in Fig. 1.

The load variation shown depicts the status of Maharashtra State Electricity Distribution Company Limited (MSEDCL), which supplies electricity to entire Maharashtra except Mumbai. The load requirement could not be met by MSEDCL and some load shedding was done. It is found that on this particular day, the peak load occured at 12 noon which was 16,548 MW with a load shedding of 2617 MW and the minimum load requirement was 11,619 MW at 3 AM which was met with no load shedding.

Fig. 2 shows the consumption of electricity by different sectors of the state economy. It can be seen that the industry sector consumes maximum amount of energy which is 39 per cent, domestic sector consumes 22.96 per cent, and agriculture sector consumes 17.59 per cent [3].

As per Maharashtra Electricity Regulatory Commission (MERC), load shedding is not the prudent way of rationing a scarce resource and the Commission has been trying to implement alternate measures to avoid load shedding. The better option shall be well thought and planned strategy to bridge the demand-supply gap as compared to unregulated or unplanned shutdown in case of a shortfall [12]. The Commission has powers to direct all distribution licensees within the state to ensure regulation of supply, distribution and consumption [13].

Table 1 gives statistics of the monthly average supply against the average demand for a period of two years. It can be seen that throughout this period, the supply has fallen short of the required energy. In order to bridge this demand and supply gap, load shedding became inevitable. Load shedding protocol is set and implemented by SLDC (Tables 2 and 3).

For the duration 2009–2010, the average demand was 13,406 MW, while for the year 2010–2011, it was 14,043 MW, i.e. a rise of 4.75 per cent. The average supply for the year 2009–2010 was 10,357 MW and for the year 2010–2011 was 11,127 MW. Thus for the year 2009–2010 the average load shedding was 2829 MW, i.e. 20.84 per cent and for the year 2010–2011 was 2916 MW, i.e. 20.54 per cent.

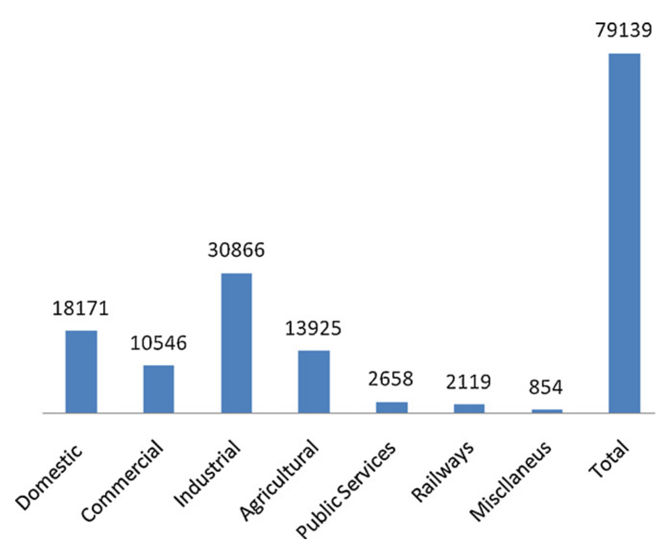

Fig. 2. Sectoral consumption of electricity in million kWh for 2009–2010 [3].

Table 1
Monthly average of energy requirement and shortfall for MSEDCL during April 2009–March 2011 [11].

Month	Monthly average demand MW	Monthly average of energy supplied MW	Monthly average of load shed MW	Percentage load shed
April-2009	14,373	11,233	3140	21.84
May-2009	13,209	7900	2654	20.09
June-2009	13,049	10,322	2727	20.89
July-2009	10,904	9221	1683	15.43
August-2009	12,613	10,082	2531	20.06
September-2009	12,094	10,044	2050	16.95
October-2009	12,847	10,392	2455	19.11
November-2009	12,558	10,098	2460	19.59
December-2009	14,167	10,831	3336	23.54
January-2010	14,462	10,960	3502	24.21
February-2010	15,137	11,426	3711	24.51
March-2010	15,456	11,765	3691	23.88
April-2010	15,714	11,767	3947	25.11
May-2010	15,448	11,301	4147	26.84
June-2010	13,068	9980	3080	23.56
July-2010	12,035	9420	2615	21.72
August-2010	11,963	9695	2268	18.95
September-2010	11,999	10,037	1962	16.35
October-2010	13,448	10,853	2595	19.29
November-2010	12,206	10,670	1536	12.58
December-2010	14,963	11,510	3453	23.07
January-2011	15,375	12,411	2964	19.27
February-2011	16,213	12,912	3301	20.36
March-2011	16,087	12,968	3119	19.38

For the year 2009–2010, minimum load shedding occurred in the month of July which was 1683 MW, i.e.15.43 per cent and the maximum load shedding took place in the month of February which was 3711 MW, i.e. 24.51%. For the period 2010–2011, the minimum load shedding took place in the month of November and was 1536 MW, i.e.12.58% and maximum was in the month of April which was 3947 MW, i.e. 25.11%.

Fig. 3 gives comparison of peak demand without and with load shedding for MSEDCL. For the year 2009–2010 the average peak demand without load shedding was 15,245 MW while for year 2010–2011 it was 15,734 MW. The average peak demand with load shedding for the year 2009–2010 was 11,252 MW and for the year 2010–2011 was 11,542 MW. Thus during the peak hours the average load shedding for the year 2009–2010 was 3993 MW and for the year 2010–2011 it was 4192 MW.

For the period April 2009 to March 2010 the peak shortage was the least in July 2009 and was 2968 MW and maximum peak shortage was 4782 MW and was in the month of November. For the period April 2010 to March 2011 the minimum peak shortage was 2920 MW in the month of September 2010 and maximum was 5496 MW in the month of May 2010.

Fig. 4 shows the variation of peak demand shortfall and average energy demand shortfall. During the year 2009–2010, the difference between the peak demand shortfall and the average demand shortfall was the minimum in December and was 467 MW and it was highest in the month of November which was 1802 MW. For the year 2010–2011 the minimum difference was during September 2010 and maximum during May 2010.

Table 2
Installed generation capacity of Maharashtra as on 31st March 2011 [15–19].

Company	Source	Installed capacity MW
MAHAGENCO	Thermal	6720
	Hydro	2531
	Natural gas	852
	Sub-total	*10,103*
Tata Power	Thermal	1580
	Hydro	444
	Renewable	100
	Sub-total	*2124*
Reliance infrastructure	Thermal	500
Ratnagiri gas and power projects Pvt Ltd	Natural gas	1967
Pench	Hydro	18
JSW energy	Thermal	600
Wardha power Co Pvt Ltd	Thermal	405
Dodson-Lindblom hydro power Pvt Ltd	Hydro	48
Independent power producers	Various	1190
	Renewable	2310
Grand total		19,265

3. Electricity supply analysis

Since the supply is made through various power companies, which are supplying either to Mumbai alone or the complete state, the demand analysis would vary for these destinations. At present, the State's power system is divided into two systems viz. (1) Mumbai, which is supplied power from Dahanu Thermal Power Station owned by Reliance Energy Limited and Tata Power. (2) Rest of the state, served by MSEDCL. Brihanmumbai Electric Supply and Transport (BEST) is a distribution company and receive power from Tata Power. Thus in Maharashtra, power requirement is met from MSEDCL, Tata Power, Reliance Energy, Central Government power projects, and Maharashtra Energy Development Agency (MEDA). Fig. 5 shows various power plants in the state. Maharashtra boasts of maximum number of thermal power plants.

Maharashtra Power Generation Company Limited (MAHAGENCO) is engaged in the business of generation and supply of electricity and has been vested with generation assets, interest in property, rights and liabilities of erstwhile Maharashtra State Electricity Board (MSEB) [14].

From Table 2, it is clear that, as on 31st March 2011 the installed capacity of the state was 19,265 MW. MAHAGENCO accounts for 52.44 per cent, followed by Tata Power 11.03 per cent, Ratnagiri Gas and Power Projects Pvt. Ltd. (RGGPPL) (Private Sector) 10.21 per cent, Reliance Energy 2.59 per cent. In addition to this, there is a central allocation of 258 MW for the state.

Fig. 5 gives an analysis of the various sources of electricity generated in the state. Thermal energy accounts for 50.89 per cent of the total power generated, hydro power accounts for 15.79 per cent

Table 3
Total energy supply with and without load shedding [11].

MSEDCL energy supply in million kWh			Mumbai energy supply in million kWh	State energy supply in million kWh		Energy shortage in million kWh
Year	With load shedding	Total requirement		With load shedding	Total requirement	
2009–10	68,414	88,106	17,810	85,151	105,916	19,689
2010–11	74,806	93,404	18,515	93,320	111,919	18,578
% Growth	9.34%	6.01%	3.96%	9.59%	5.66%	Reduction 5.64%

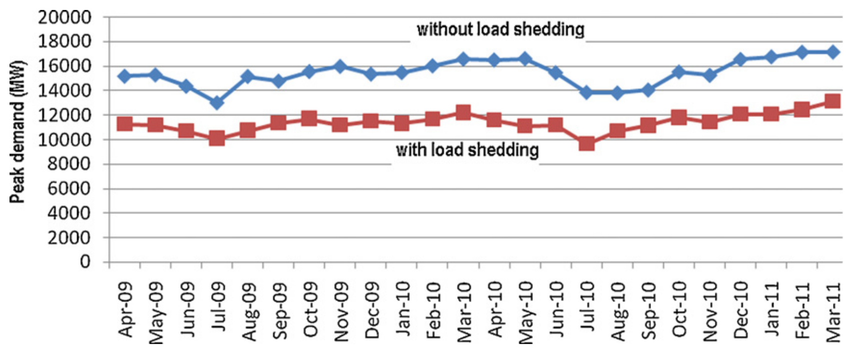

Fig. 3. Variation of peak demand for MSEDCL [11].

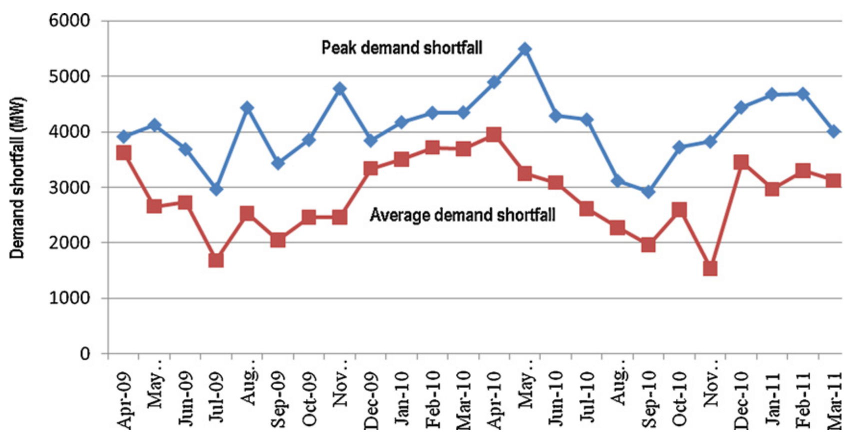

Fig. 4. Variation of peak demand and monthly energy shortage for MSEDCL [11].

and power generated using Natural gas as fuel accounts for 14.63 per cent. Power supplied by renewable energy is 12.51 per cent and the captive power accounts for 6.18 per cent.

In the year 2010–2011, the total electricity demand in the state was 111,919 million kWh, which was 5.66 per cent more than the previous year. The load shedding reduction was 5.64 per cent in the

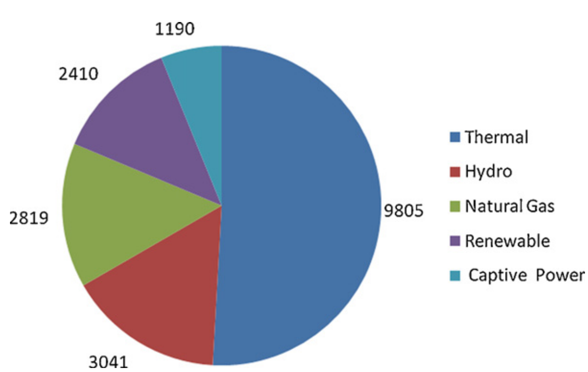

Fig. 5. Different power plants in Maharashtra.

year 2010–2011 compared to previous year. Mumbai (state capital) received 18,515 million kWh power which is 3.96 per cent more than the year 2009–10.

4. SLDC data on major troubles in the existing plants

Table 4 gives the various causes of the outages/tripping of the power generating units on a typical day 31 March 2011. Along with the outages of the generating units, tripping of 400 kV, 220 kV and 132 kV lines are the common occurrences. As a result, the on-line capacity reduces compared to installed capacity. For example, on the day of 31 March 2011 even though the installed capacity is 19,265 MW, the on-line capacity was 15,574 MW. Thus, further augmenting the capacity can give relief to the power ridden state, but it cannot be the holistic solution to the problem. Hence, it is important to make optimum use of the available energy sources such as renewables, captive power plants.

Periodic preventive maintenance practices such as repair or replacement of worn out boiler tubes, condenser tubes, water wall tubes, refueling work, maintaining auxiliary systems, maintaining proper furnace pressure, replacement of conductors, line capacity

Table 4
Details of Generating Unit Outages/Tripping for 31 March 2011 [11].

Name of generating unit	Capacity	Tripped date	Reason of outage
Planned outage			
Central sector Tarapur 2	80	04/03/2011	Refueling work
Dabhol 1B	230	15/03/2011	Up gradation work
Central sector Tarapur 1	80	22/03/2011	Seven days maintenance work
Central sector NTPC(K-3)	210	31/03/2011	Annual overhaul
Central sector Sipat-5	500	01/04/2011	Annual overhaul
Forced outage			
Khaparkheda unit 3	210	28/03/2011	Boiler tube leakage
Uran unit 5	108	30/03/2011	Boiler tube leakage
CPP JSW U1	300	30/03/2011	Tripped due to tripping of new Koyna-II
CPP JSW U2	300	31/03/2011	Tripped due to tripping of new Koyna-II
Central sector NTPC (K-2)	210	01/04/2011	Boiler tube leakage
Central sector NTPC (V-2)	210	01/04/2011	Boiler license renewal
CPP WPCL U-2	135	01/04/2011	Unit W/D up to 06:00 h, since there is no buyer
CPP WPCL U-1	135	01/04/2011	Unit W/D up to 06:00 h, since there is no buyer
Tata Trombay 5	500	01/04/2011	Tripped on jerk
Tata Trombay 8	250	01/04/2011	Tripped on jerk

augmentation, oil filtration work and monitoring of feeders. should be carried out.

5. Towards sustainable electricity supply for maharashtra

As shown in Fig. 6, around 50.89 per cent power generation in the state is thermal based. Out of the total installed capacity in the state, the electricity generation using renewable energy is 12.51 per cent. India has a known reserve of 660 MMT of crude oil and 648 billion m^3 of natural gas. Only a part of this total reserve may be feasible to exploit, due to technical constraints and economic point of view. Along with these facts, the present and expected consumption rates, the estimate is that these reserves may not last more than ten years [20]. The indigenous production is only 33 MMT which is less than 50% of our annual requirements. The hard coal reserves in India are around 246 billion tonnes, of which 92 billion tonnes are proven. The Indian coal may last for a century or beyond [21]. Thus, relying on heavy oil imports and depending too much on thermal power generation, which depends on fast depleting fossil fuels, cause a concern for the energy security of the nation. Also combustion of fossil fuels creates carbon dioxide which is contributing to global warming. Combustion of these fossil fuels is considered to be the largest contributing factor to the release of greenhouse gases into the atmosphere. Fig. 7 shows the rise in per capita CO_2 emissions in metric tonnes (MT) for India. The rising CO_2 emissions from power plants are a bigger concern for growing economies such as India and the state.

The need of the hour is to increase the presence of renewable energy in the Indian power sector. Government of India (GoI) and MERC devised regulatory framework with specific provisions for the promotion of environment compliant renewable energy [23–27]. MERC has taken up all the aspects relevant to buoy-up

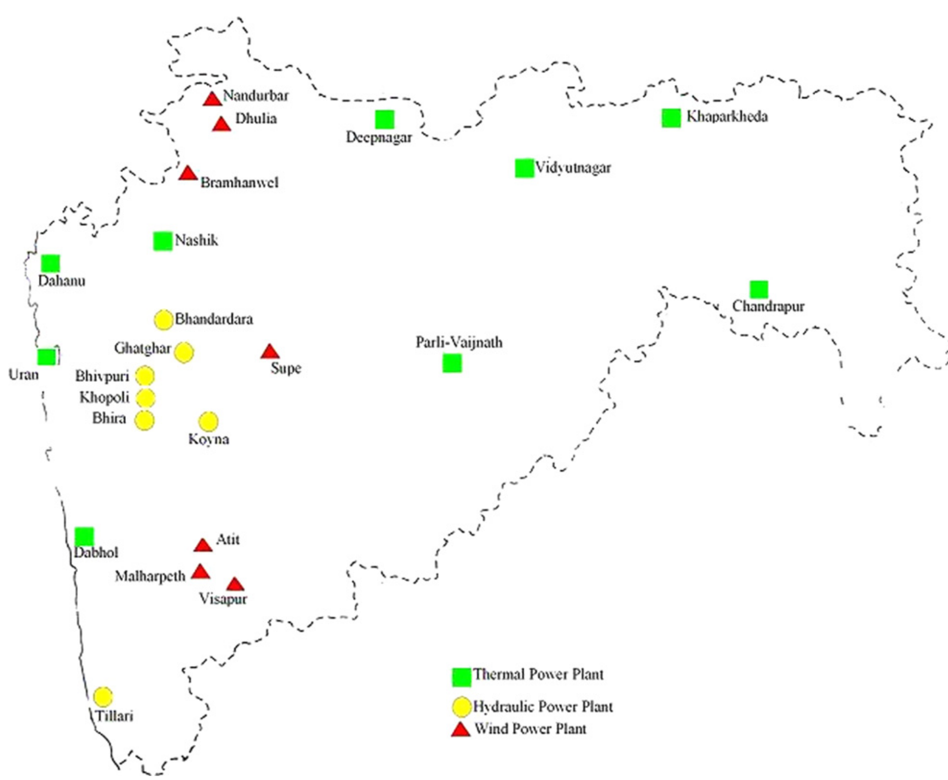

Fig. 6. Electricity generation in the State (MW).

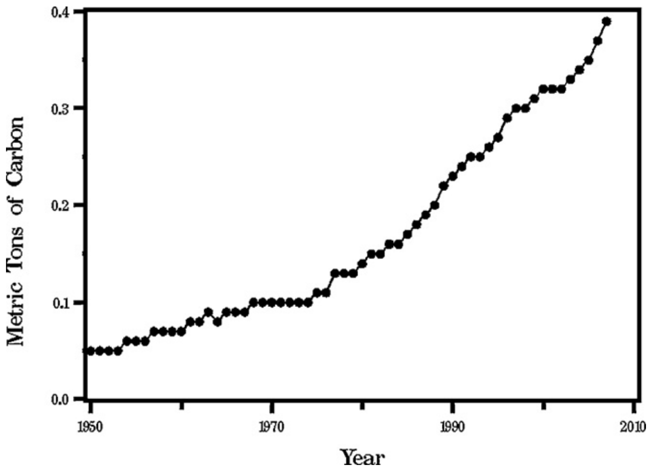

Fig. 7. Per capita CO_2 emission for India [22].

renewable energy such as, the legal and policy framework, renewable energy development in the state, renewable purchase obligation framework, renewable energy pricing framework, grid connectivity framework from time to time at various fora [28]. Various authors have attached significance to the development of sustainable energy for the growth of electricity in India. Goyal and Jha [29] have suggested some of the measures to be taken by State electricity Regulatory Commissions (SERC) to promote renewable energy. Obstacles to the dissemination of renewable energy technologies in the state have been discussed by Reddy [30]. Hiremath et al. [31] have presented the importance of the renewable energy in India. They have also given the appropriate power supply model for rural India.

From this perspective, renewable energy as a source of power has gained a lot of importance. Development of renewable energy in the state is done under the aegis of MEDA. As per MEDA, the state has a total energy potential of 8839 MW, whereas the achievement as on date 31 March 2011 is that of 2310 MW. Thus there is a lot of untapped potential as far as renewable energy is concerned.

6. Alternative sources for meeting power demand

6.1. Captive power

Captive power is considered one of the options which quickly add to the installed capacity. Ministry of Power, Government of Maharashtra (GoM) and MERC have formed policies to encourage captive power [32–36]. There are total ninety captive power plants (CPP) operational in the state. The total captive plant capacity is 1190 MW. Amongst the CPP having capacity greater than 50 MW, Reliance Energy Ltd. Patalganga has a naphtha based CPP of 92.34 MW capacity, ONGC/IPG CPU plant in Uran has 59.6 MW capacity which is gas based while Indorama Synthetics, Butibori Nagpur has a diesel based CPP of 52.62 MW capacity. The captive power generation with Heavy Fuel Oil (HFO) as fuel is 124.59 MW, diesel as fuel is 87.13 MW, coal is 200.25 MW, naphtha as fuel is 99.34 MW, bagasse is 46.2 MW and biogas is just 1.5 MW [37]. In the context of increasing demand supply gap, policy makers are looking for all possible sources of electricity generation due to encouraging policies new captive power plants are coming up in the state.

6.2. Wind power

Wind energy is one of the cleanest sources of power. The installed capacity of wind power projects in India is far below the gross potential ($\leq$15%) [38]. In the state, to induce private investment, MEDA set up demonstration projects of 11.09 MW capacities with support from Ministry of New and Renewable Energy (MNRE) and state government [39]. The GoM has announced preferential tariffs. MERC has given directions to all distribution licensees to purchase minimum quantum of electricity annually from renewable sources expressed as a percentage of their total consumption [40]. These efforts have facilitated private investments of Rs. 10, 350 Crores in the wind sector [39]. As on 31 March 2011, the installed capacity in the wind sector is 2310 MW. The wind resource assessment (WRA) has been carried out by Center for Wind Energy Technology (C-WET) in co-ordination with MEDA. WRA of another 140 sites is complete and 40 sites have been found feasible for wind power projects in the state. An annual average wind power density more than 200 W/m^2 is found at these sites. WRA of 148 sites is in progress [39]. The Suzlon Company's site near Dhulia, a district place in Maharashtra has an installed capacity of 400 MW. A plan to add 600 MW is in progress. This wind park in Maharashtra, when complete, is going to be the world's largest wind park with a capacity of 1000 MW. The innovation in technology is also a reason behind the fast development in the wind sector. The amount of electricity produced annually by a modern wind turbine is 180 times more at less than half the cost per unit kWh than its equivalent 20 years ago. The largest turbines being manufactured now are having a rotor diameter 126 m and of rated power of 5 MW capacity [40].

6.3. Biomass

The use of biomass as an energy source has increased and is approximately 14 per cent of world's final energy consumption [41]. The amount of dry biomass produced globally by photosynthesis is around 220 billion tonnes having a conversion efficiency of 1 per cent [42–44]. The MERC has declared preferential tariff policy. It has fixed tariff of Rs. 3.04 per unit of the power generated and an increase of Rs. 0.03 per year per unit. Further, an interim tariff of Rs. 4.98 per unit was also declared [45]. Ministry of New and Renewable Energy (MNRE), Government of India is giving excise exemption and concession in custom duty on the procurement of equipments [46]. As a result, there is an increase in private sector investment. The potential of biomass in the state is assessed to be 781 MW. MEDA has so far issued consent to 34 projects having total capacity of 368.5 MW.

6.4. Bagasse

Bagasse is by-product of sugar cane that is used as a fuel in boiler. Use of high pressure boilers of 66 bar or 87 bar and above make such power projects profitable. The potential in the state is 1250 MW and total twenty six bagasse based cogeneration sites having collective capacity of 330.5 MW are commissioned in the state [39]. Based on the type of technology configuration, a reduction of 0.8–1.2 kg of CO_2 per kWh has been estimated [47]. Further, SO_2, NO*x* and particulate emissions are low compared to coal and other fossil fuels. The electricity generation potential of bagasse can be calculated using the sugar cane data. Processing of one tonne of sugarcane, results in a third of tonne of bagasse waste. Electricity generated from one kilogram of bagasse burned is around one third of a kWh. The calorific value varies with fiber content of the cane which varies between 11 and 20 per cent [48]. The power generation potential can be easily increased by using equipments and systems for reduction of steam and power in sugar processes from present 50–52 per cent steam on cane and 22 units of electricity per tonne of cane crushed to 42–45 per cent steam on cane and 16 units of electricity per tonne of cane crushed, also for manufacture of by-products [47]. Thus, bagasse is a prudent source of power for the state.

7. Conclusion

From the above discussion, it is clear that the state is undergoing acute shortage of electricity as against the growing needs of service and industrial sector economies. The maximum load shedding was of the order of 25.11 per cent during last two years. On the power supply front, participation of government owned plants is found to be predominant. However, there is a good presence of private sector and independent power producers. The power production by private sector will grow if these policies remain in force for a longer period. The continuation of the policy to purchase surplus power by the distribution company will enhance the growth of the captive power plants in the state. The role of regulatory commission has made the energy management more professional. The state is predominately powered by thermal power plants but a vast potential of renewables especially bagasse and wind is a positive sign.

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